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Phloem Necrosis

A Virus Disease of the American Elm

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INTRODUCTION

The American elm, besides being tenth among hardwoods in stumpage and log sales and first in value as a shade tree, is now assuming a new importance in the protective concealment of military and defense structures. Therefore knowledge concerning phloem necrosis as a destructive virus disease causing an epidemic dying of American elms in the region of the central and lower Ohio River watershed is vital. This disease was first identified as a virus disease in 1938 following investigations of the dying of many elms in Ohio, which was first observed at Ironton in 1918, at Dayton in 1927, and at Chillicothe in 1935.

Although it is not known when and where the disease originated, observations and reports indicate that it may have been prevalent in parts of Indiana, Illinois, and Kentucky for many years. A similar epidemic dying of elms in Kentucky was reported by H. Garman in 1893 and 1899, and in 1912 S. A. Forbes reported the dying of elms described by Garman as having occurred in Illinois since 1882. These early epidemics and the symptoms of the disease described by Garman and Forbes resemble elm phloem necrosis in many respects. However, the cause was not definitely determined, and the symptoms described are inadequate for positive identification of the disease as elm phloem necrosis.

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DISTRIBUTION AND HOSTS OF THE DISEASE

Although no systematic survey has been made to determine the exact distribution of the disease, reports and specimens received and incidental survey indicate that it is present in a large area. It is known to be generally distributed in the southern halves of Ohio, Indiana, and Illinois; southeastern Missouri; northwestern Tennessee; Kentucky; and the western part of West Virginia. In some cities and towns of this area the disease has killed from 50 to 75 percent of the American elms during the past 5 years. Both wild and planted elms are affected, and neither age nor tree vigor seems to influence their susceptibility nor to enhance their chances of survival. The destructive Dutch elm disease and its two most important insect carriers have been found within this area. Trees killed by phloem necrosis are attacked by the beetles, increasing the potential sources and means of spread of the Dutch elm disease fungus. Moreover, the external symptoms of the two diseases are sometimes very similar. These factors complicate the efforts to control the Dutch elm disease.

The American elm (*Ulmus americana* L.) and its varieties, the vase and moline elms, are very susceptible to phloem necrosis. A few affected trees with characteristics of the slippery elm (*Ulmus fulva* Michx.) have been observed, but diseased trees of this species have been observed so rarely that the affected trees may have been hybrids. The disease is not known to affect other native or exotic elm species, although tests to determine their susceptibility are not yet complete, and some may be susceptible or carry the virus without showing disease symptoms.

SYMPTOMS OF THE DISEASE

Artificial-inoculation experiments have indicated that trees may be infected for 6 months to 1 or more years before symptoms of the disease become apparent. After symptoms appear the trees usually die within 12 to 18 months, although some die within 3 or 4 weeks. In some cases, trees with pronounced disease symptoms have been known to survive for 2 or more years, but this is not common. All diseased trees observed to date have eventually died, no positive cases of recovery having been observed.

Foliar symptoms of elm phloem necrosis vary, but they are similar in some respects to those produced by drought, girdling, some nutrient deficiencies, and certain other diseases. There is usually a gradual decline throughout the entire crown, but symptoms may first appear on a single branch or a portion of the top. In large trees, the first evidence of disease is usually a slight scarcity of foliage in the extreme top or at the outer tips of branches. Leaves droop and the leaf blades curl upward at their margins, producing a troughlike effect. This curling makes the leaves appear narrow and partially accounts for the appearance of sparse foliage. The under surfaces of curled leaves are exposed to view, causing the foliage to appear light green or grayish green when seen from a distance. Later, scarcity of foliage becomes pronounced throughout the entire crown, leaves become yellowish green, then more definitely yellow, and some on lower suckers become dry and brown (fig. 1). Defoliation follows soon thereafter and the tree dies. On small trees, and some large ones, there is usually no pronounced sparseness or curling of foliage, but yellowing becomes pronounced throughout the entire crown some time before defoliation and death. Other apparently normal and vigorous large or small trees may suddenly wilt and die within a few weeks, leaving dried, dead leaves adhering to the branches (fig. 2).

Roots of trees affected by elm phloem necrosis die, the small fibrous ones first. A typical discoloration, confined to the inner bark or phloem tissue, develops in large roots before they die and frequently extends into the trunk and some branches (fig. 3). In large trees the discoloration is usually found only in large roots and the lower part of the trunk just before the tree dies. In most small trees and a few large ones it can also be found in the upper part of the trunk and in some of the branches; sometimes it becomes pronounced in large or small trees prior to the appearance of external symptoms. The discoloration is at first yellow, followed by a typical "butterscotch" or raw-sienna color

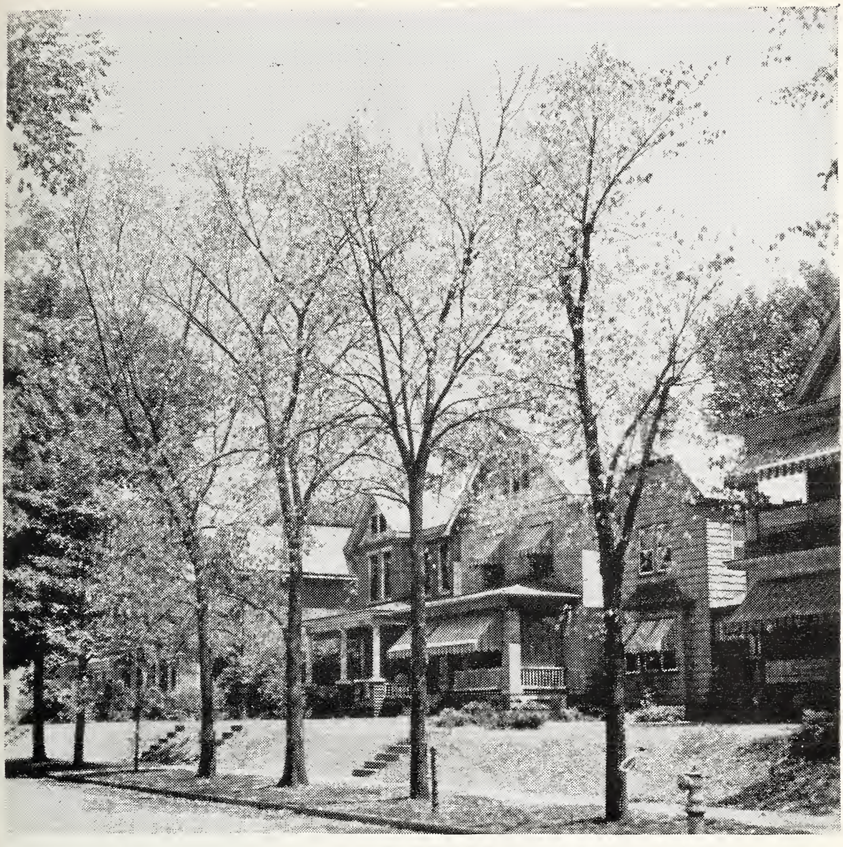

Figure 1.—American elms in an advanced stage of elm phloem necrosis. Sparseness of foliage is pronounced and leaves are yellow. The inner bark of buttress roots and lower trunk is discolored. (August 1940.)

that often contains small, scattered brown or black flecks. Later, it becomes dark brown and necrotic. The moderately discolored phloem tissue has a faint odor of wintergreen, which cannot be detected in bark of healthy American elms. The odor can best be detected after confining a small quantity of the discolored phloem in a small, stoppered vial for a few minutes or after holding a small amount of it in the closed hand for a short time.

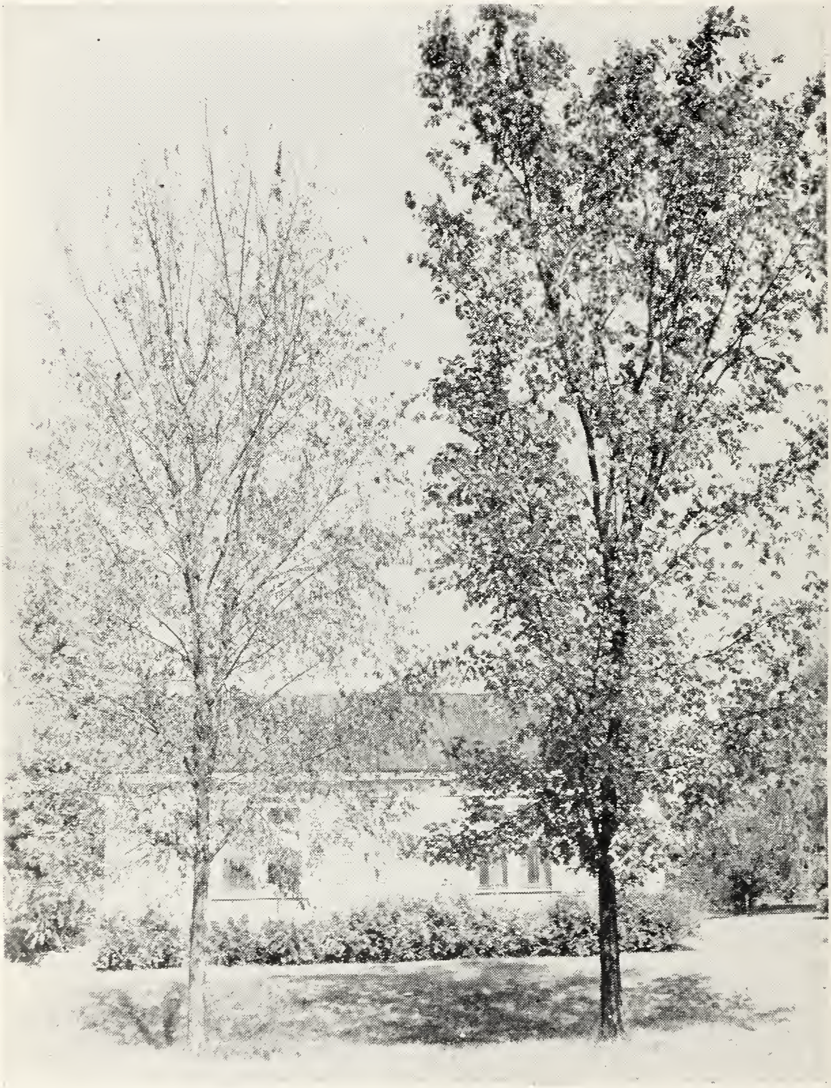

FIGURE 2.—The elm on the left appeared healthy and vigorous 2 weeks before sudden wilting and death occurred, although at that time phloem discoloration was pronounced in roots, trunk, and lower branches. External symptoms are strikingly similar to those exhibited by trees with a severe case of the Dutch elm disease. (August 1940.)

These two symptoms, the phloem discoloration and the wintergreen odor, are specific for elm phloem necrosis and serve to differentiate it from all other known tree diseases. The external symptoms described do not differentiate elm phloem necrosis with certainty from other diseases, but they indicate that a tree is a phloem necrosis suspect. For positive identification of the disease, an examination must be made for the presence of the typical discoloration and the wintergreen odor of the inner bark. Small specimens of bark should be removed from the lower trunk or buttress roots of phloem necrosis suspects and examined for these specific symptoms. Since normal bark from healthy elm becomes brown after being exposed to the air for a short time, the bark samples should be examined for the typical discoloration as soon as they are taken. If these symptoms are not found in the inner bark after sampling several buttress roots and several points around the circumference of the lower trunk, the disease is probably not elm phloem necrosis. A further examination of the tree must then be made for other possible causes of decline, such as the wilt diseases that produce a brown streaking in the wood of affected trunks or branches (fig. 4), cankers, and other troubles.

CAUSAL AGENCY

The causal agency of elm phloem necrosis is a virus. Examples of other plant-virus diseases are tobacco mosaic, aster yellows, peach yellows, and raspberry leaf curl. Measles, smallpox, infantile paralysis, and rabies are examples of some virus diseases of man. Virus diseases are highly infectious, a character that differentiates them from noninfectious plant diseases caused by drought, nutrient deficiencies, and other physiological troubles. Virus diseases differ from other infectious diseases caused by bacteria, fungi, and protozoa in that these latter causal agencies are macroscopically or microscopically visible, whereas viruses are too small to be seen under the highest magnification attained by the ordinary microscope. They are dependent on living tissue, often that of their specific host, for multiplication and growth. A few viruses causing plant diseases have been isolated by chemical methods and analyses of some of them indicate that they are proteins. Attempted isolations of others have failed and their nature remains unknown. Whether they are living organisms or of a purely chemical nature has not yet been definitely established. Knowledge of them has been obtained through studies of their behavior, properties, and host reactions. Although it is difficult to give a specific, concise definition of virus diseases, they may be regarded as characterized by their highly infectious nature in the absence of any recognizable causal agency.

No visible causal agency of elm phloem necrosis has been found. Extensive attempts to isolate a causal organism from dead and dying roots, trunks, and branches of approximately 500 diseased trees, utilizing common and specialized methods for the isolation of fungi, bacteria, and flagellate organisms, have failed. No organism was obtained consistently; approximately 50 percent of the attempted isolations remained sterile. Inoculations of healthy trees with the organisms obtained did not produce the disease. Furthermore, when microscopical examinations of both living and fixed, stained diseased tis-

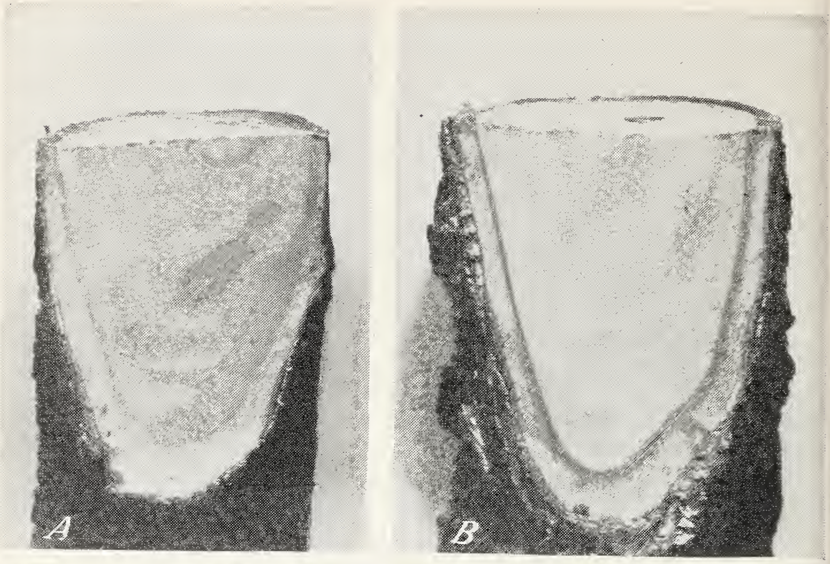

FIGURE 3.—*A*, Section through the lower trunk of a healthy tree; *B*, yellow or yellowish-brown discoloration of the inner bark produced by elm phloem necrosis.

sues were made, no bacteria, fungi, or flagellate organisms were found consistently present in the tissues. Only occasional bacteria and fungi were found, and these were confined mostly to dead and dying roots. Healthy elms inoculated directly with diseased tissues, as a possible check against the causal agency being an organism that would not

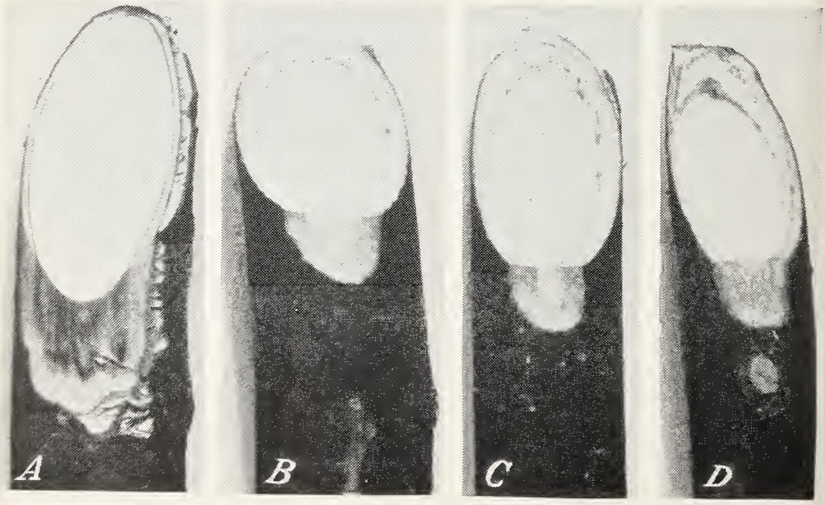

FIGURE 4.—Comparison of internal symptoms produced by elm phloem necrosis with those produced by the fungus-induced wilts: *A*, The internal-bark discoloration produced by elm phloem necrosis; *B*, the sapwood discoloration produced by the Dutch elm disease; *C*, verticillium wilt; and *D*, elm dieback.

yield to known culture technique, have remained healthy. Healthy elms with wounded roots have remained healthy when planted in soil obtained under diseased trees and when planted in a compost consisting of 50 percent soil and 50 percent diseased roots, thus indicating that the cause of the disease is not an agency that can spread from tree to tree in contaminated soil.

The transmissibility or infectious nature of elm phloem necrosis has been demonstrated. Healthy elms grafted with bark patches or whole sections of roots and branches taken from diseased trees became diseased within 6 to 24 months, specific symptoms of phloem necrosis appearing in 75 percent of the trees grafted with diseased roots and in 90 percent of the trees grafted with diseased branches or bark patches. However, only those trees making active union with diseased scions or bark patches became diseased, nearby ungrafted trees and those on which attempted grafts were unsuccessful remaining healthy.

These investigations, revealing the transmissibility of elm phloem necrosis and its infectious nature in the absence of any visible or recognizable parasitic organism, indicate that the causal agency is a virus. Properties of the virus causing elm phloem necrosis and its possible relationship with other viruses causing plant diseases are not yet known.

SPREAD OF THE DISEASE

In Ohio, where the disease has been under close observation for several years, spread of phloem necrosis has been rapid. Affected trees have suddenly appeared in localities 10 to 25 miles distant from any known disease center. In these localities the disease has reached epidemic proportions within 1 to 3 years, although little spread may have occurred from them into nearby localities during that period.

Root grafting of elms sometimes occurs under natural growing conditions. As phloem necrosis is transmitted by grafting, localized spread of the disease sometimes occurs in this manner. However, spread by root grafting can occur only in plantings along city streets and in dense wild stands where elms grow in close proximity to one another. It cannot account for the more extensive spread of the disease during recent years. How extensive spread occurs is not known, but observations on natural spread of the disease in the field and the known means of transmission of other virus diseases suggest that the phloem necrosis virus may be carried by some type of sucking insect. To investigate this question, the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry have established a cooperative laboratory at Columbus, Ohio, where a search is being made for possible insect carriers of the virus.

No evidence has been obtained that the disease is spread by pruning tools. Attempts to transmit the disease to healthy elms by inoculating them with sap expressed from diseased trees have not been successful. Neither has the disease been transmitted to healthy elms by direct inoculation through wounds with tissues from diseased roots, trunks, or branches. However, all pruning tools should be treated with alcohol or some other effective disinfectant as a precaution against spreading other diseases that may be present and may be spread in this manner.

CONTROL

Some experimental work on control of elm phloem necrosis is in progress, but results are not yet available. Until further information on the disease is obtained, no cure for trees affected by elm phloem necrosis or measures for the protection of healthy trees can be recommended. Fertilizer applications and pruning have been tested, but they have not enabled trees to resist infection or recover from the disease. On the basis of information available on other virus diseases, spraying for the control of elm phloem necrosis is probably ineffective. Also, control by eradication would seem to be only a remote possibility, as the disease is common on both wild and planted elms over a large area and some trees may be diseased for 1 or more years before showing disease symptoms.

On the basis of present information, the development of disease-resistant elms by breeding and selection seems to offer the most promising method of controlling phloem necrosis. Some elm species do not seem to be affected, indicating the possibility of developing disease-resistant hybrids. Also, there may be some resistant American elms from which propagating stock can be obtained, since a few trees are known that have survived in areas of epidemic outbreaks of the disease.

Until further information on the disease is available and means of spread and control measures are determined, trees other than the American elm and its varieties should be used for replanting purposes within the disease area. Because spread of phloem necrosis in future years cannot be predicted, possible extensive spread of the disease should be considered in tree-planting programs outside the present known disease area. In any locality, extensive plantings of American elms or any other single species should be discouraged, because conditions are thereby created that are exceptionally favorable to the development of epidemic outbreaks of destructive plant-disease pests to which the species is susceptible. One disease may destroy an entire planting of a single species, but it is not likely to affect all species in a mixed planting.

SUMMARY

Elm phloem necrosis is a virus disease causing an epidemic dying of American elms in the region of the central and lower Ohio River watershed.

The disease is identified by examining the inner bark of buttress roots or the lower trunk of phloem necrosis suspects for a yellow, yellowish-brown, or "butterscotch" discoloration and a faint odor of wintergreen. The discoloration is not usually found in branches, and it never occurs in the wood.

Means of spread of the disease under natural field conditions are not known. The disease is readily transmitted by grafting.

No cure is known for trees affected by the disease at the present time, and no measure for the protection of healthy trees has proved effective.

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